A TB-based surface emissivity transformation for stratifying/indexing *a-priori* passive MW data

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1) JPL/Caltech
2) Univ. of Oklahoma
3) Univ. of Maryland/ESSIC
4) NASA/GSFC
5) Univ. of Tokyo/JPL and JSPS Scholar

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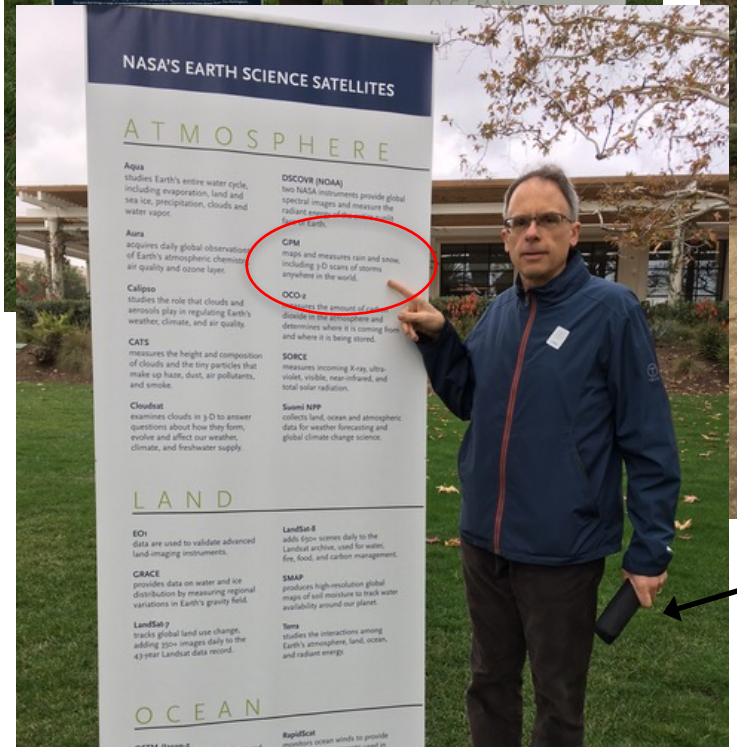
Update on 2BCSATGPM for Version 5

- Collection of ±15-min coincidences between CloudSat and GPM-core
- Quasi 3-frequency radar profiles at Ku-, Ka- and W-band alongside GMI 13-channel radiometer.
- Will be updated with latest CloudSat (2B-PRECIP-COLUMN, which is used by 2C-RAIN-PROFILE and 2C-SNOW-PROFILE), when CloudSat DPC finishes reprocessing
- Request to add 1C TB and NPP-ATMS coincidences. Anything else let me know.
- If requested, fairly easy to extend back to June 2006 during the TRMM-PR era, after TRMM reprocessing

Listening for GPM……

….an innovative “soundscape” experience representing the movement of NASA Earth Science satellites. Inside the shell-shaped sculpture, distinctive sounds are emitted as each satellite passes overhead: a human voice, the crashing of a wave, a tree branch moving, a frog croaking. Each sound interprets one of the satellites’ missions.



umbrella

Huntington Gardens
Near Caltech

Rationale

- A main constraint on the interpretation of passive microwave TB for precipitation is the “background” – the surface emissivity, or more generally, the joint surface and atmospheric moisture/temperature state.

- Since these are generally not well-known at the time of the satellite observation, this information is brought in by interpolating relatively coarse-scale weather prediction models, and surface classifications.

- Selection of these state variables is important since they suggest a way to index and guide extensive *a-priori* data searches, to isolate candidates that are congruent to the TB observations.

- However there are really few constraints on what parameters to use for guiding this indexing and searching, as long as the identical parameters that were used to construct the *a-priori* data are available at the satellite observation time.

Methodology

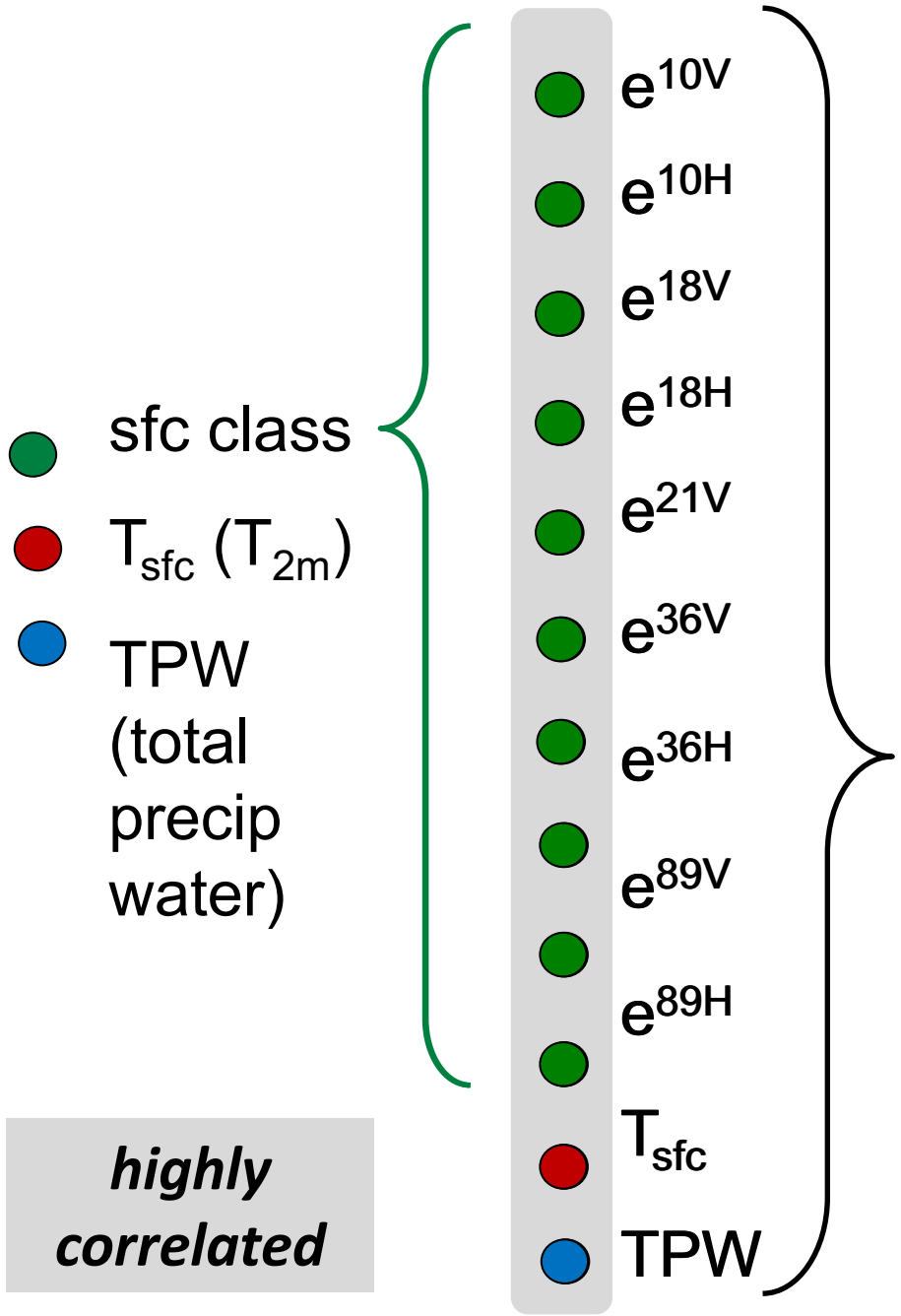
- Most of the time it is not raining, at least from the perspective of the low-end sensitivity of the core reference DPR.

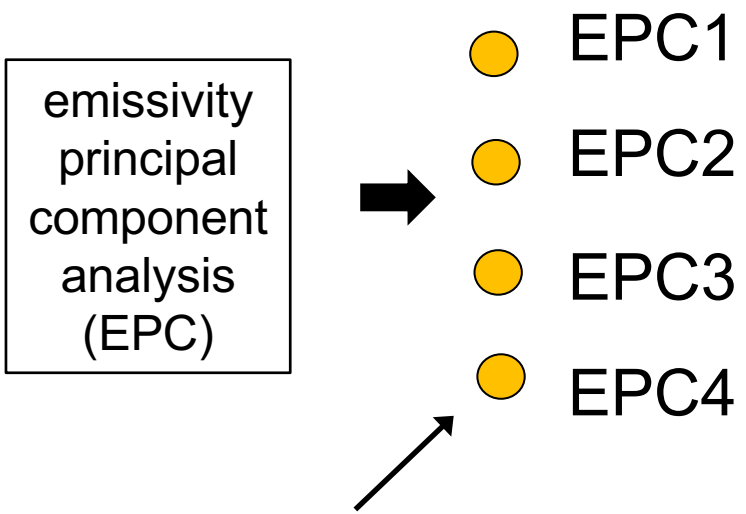
- Interrogate the information contained in these “non-raining” observations, to stratify and index the large *a-priori* data, and to perform the precipitation profile retrieval under all conditions.

- Use a single algorithm, let the observations guide (as much as possible) the *a-priori* search.

Principle

Ideally, if one could obtain a reasonable estimate of the emissivity vector at the observation time, this formulation would better accommodate short time changes in the surface emissivity properties - or work across all surfaces at the same time

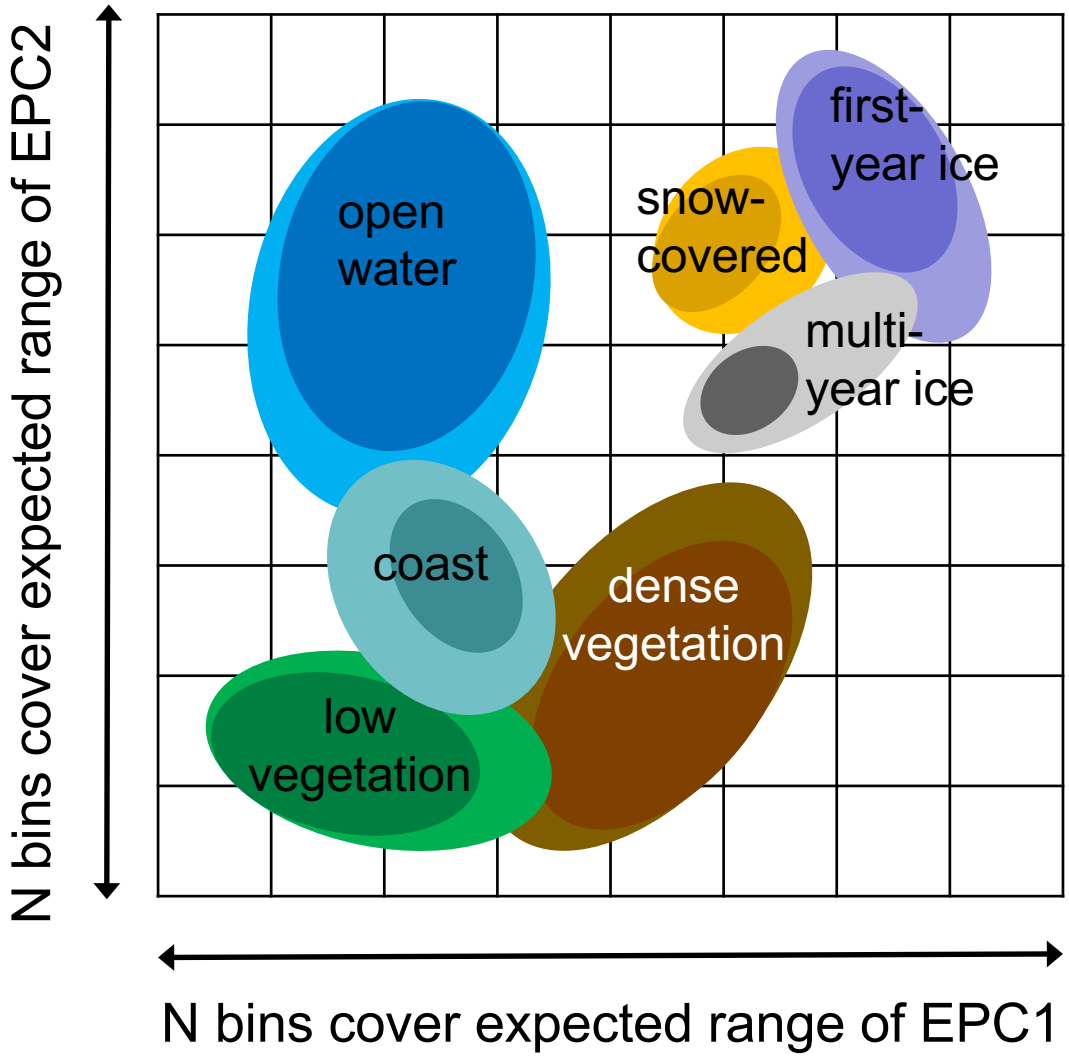




first four EPC explain the vast majority of the joint variability

Use these to index and search

Simplified 2-D Example: Low-Order Terms



(not quantitative – for illustrative and conceptual purposes only)

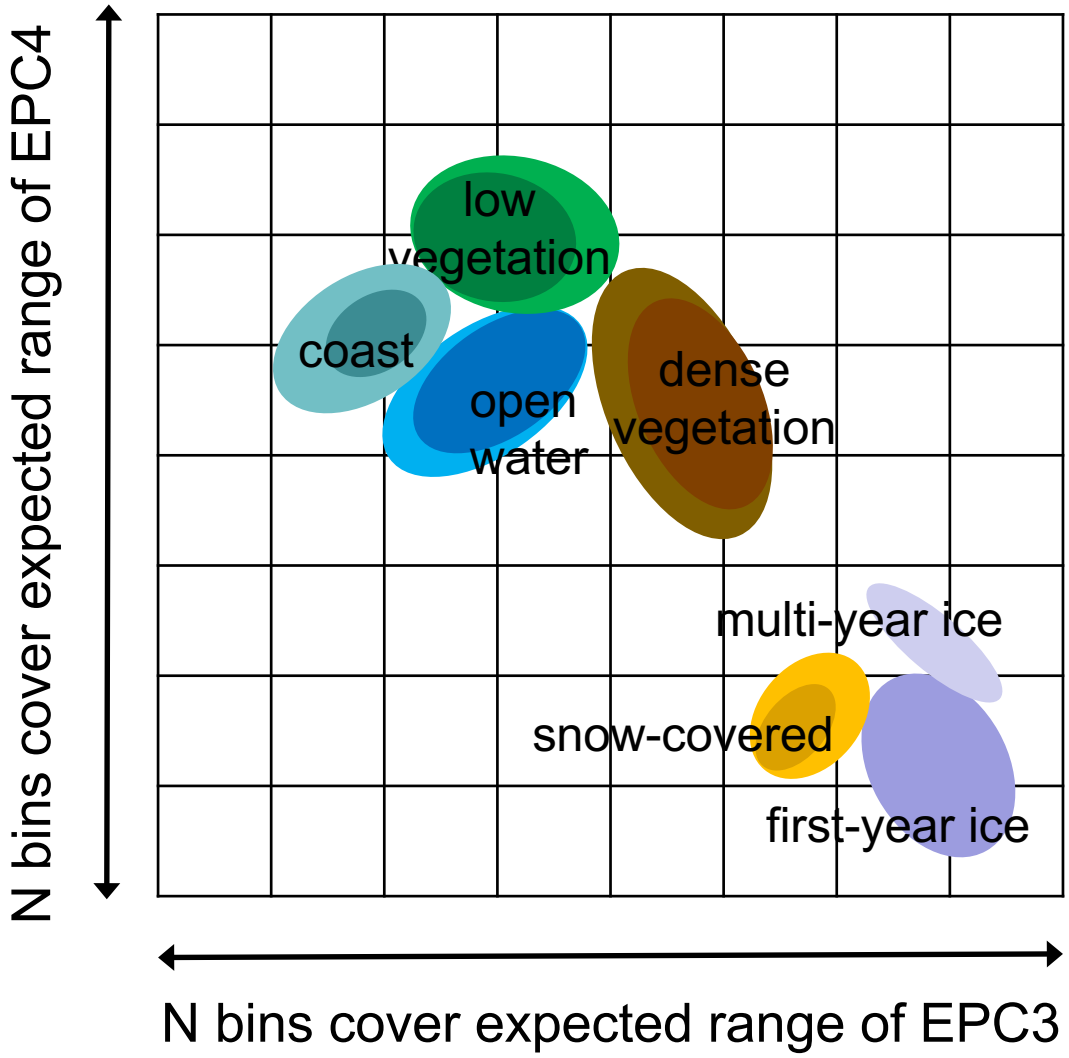
Different kinds of surfaces self-arrange into different areas of the database

While the clusters associated with typical surfaces are largely distinct, there is always some overlap

As increasing clouds/precipitation enters the scene, EPC1 and EPC2 only slightly displacement from ”no-cloud” clusters

Retains similar surface types for all scenes

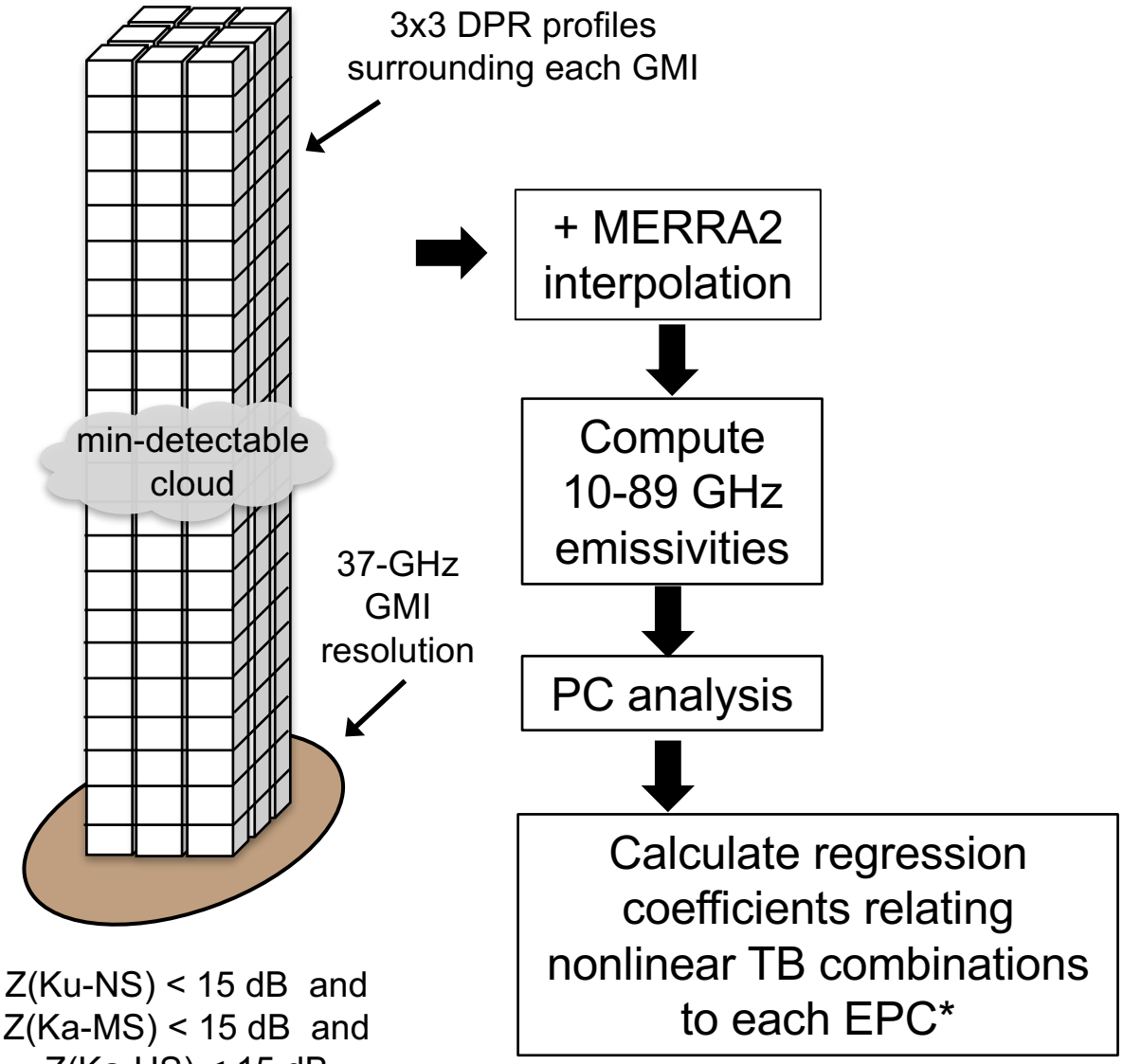
Simplified 2-D Example: Higher-Order Terms



(not quantitative – for illustrative and conceptual purposes only)

At the same time, the higher order (smaller) EPC3 and EPC4 terms are significantly displaced from their ”no-cloud” clusters

Provides a continuous transition from non-precipitating to increasingly heavy precipitating conditions



Z(Ku-NS) < 15 dB and
Z(Ka-MS) < 15 dB and
Z(Ka-HS) < 15 dB
(all bins) ➔ "no cloud"

One-time process

End result is a transformation between TB and EPC space (and vice-versa)

Has been done for other MW sensors with DPR coincidences (see poster 223)

*Turk, F.J., Haddad, Z.S. & You, Y., 2016, Estimating Non-Raining Surface Parameters to Assist GPM Constellation Radiometer Precipitation Algorithms, *J. Atmos. Oceanic Technol.*, 33(2016), pp. 1333-1353.

Extension to All Scenes

- As clouds and precipitation enter the TB scenes, part of the EPC structure is displaced from its no-cloud range. EPC begins to carry more information on clouds; as cloud extinction/scattering increases, surface becomes more opaque (i.e., emissivity less important).

- Suggests an alternate way to cluster a large database for efficient Bayesian-based inversion techniques for GMI and other sensors

- The *a-priori* dataset should be extensive enough to capture the full range and frequency of occurrence of all underlying variability in nature…surface, rain, weather systems, etc.

- Here, we constructed observational *a-priori* datasets.

- See poster 223 for example on use of GPM coincidences for the non-GPM radiometers, which don't have a companion radar.

One-Year (Sept 2014-Oct 2015) Matched DPR-GMI

- One full year of pixel-matched GMI and DPR data was created from the 1-year database provided by S. Ringerud. Each orbit was written to a file as sequential binary record structures with GMI TB, Ku/Ka measured Z profile, EPC, MERRA2 data, Ku-only and Ku+Ka precipitation estimates from the current DPR-only and CMB (DPR+GMI; CORRA) algorithms, TELSEM surface index

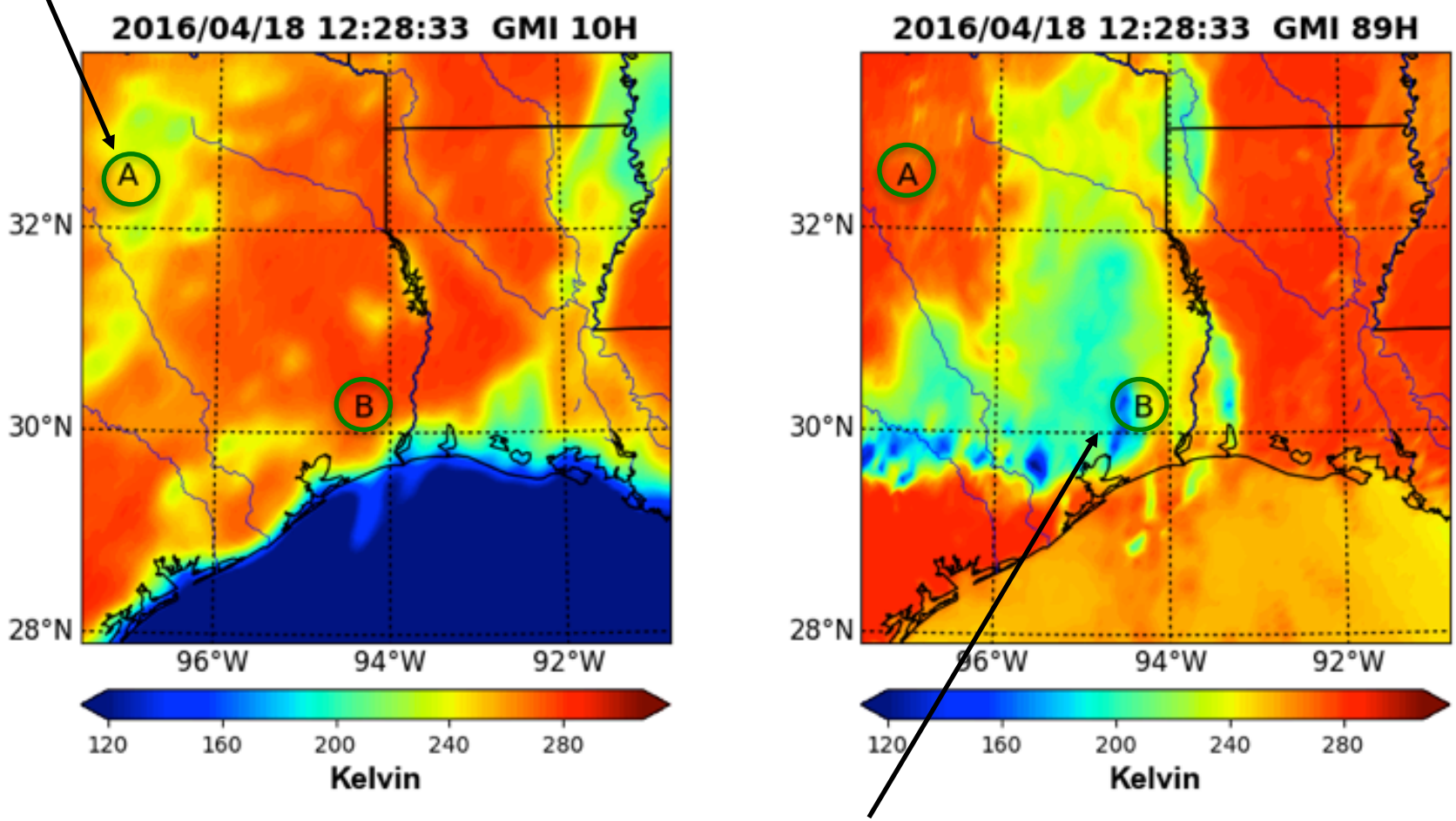
- From this, the histograms of the first four EPCs were determined, and divided into ten equal-density spaced bins. Defines a data "cube" indexed by N=10x10x10x10= 10000 total bins. Each pixel populates one of the bins.

- **Nothing is lost here**….simply a reorganization of the dataset to make the *a-priori* search in EPC space much faster.

- For efficiency, the required index bin files are first identified, then only these files are opened one time (all pixels for index file 1, all pixels for index file 2, etc).

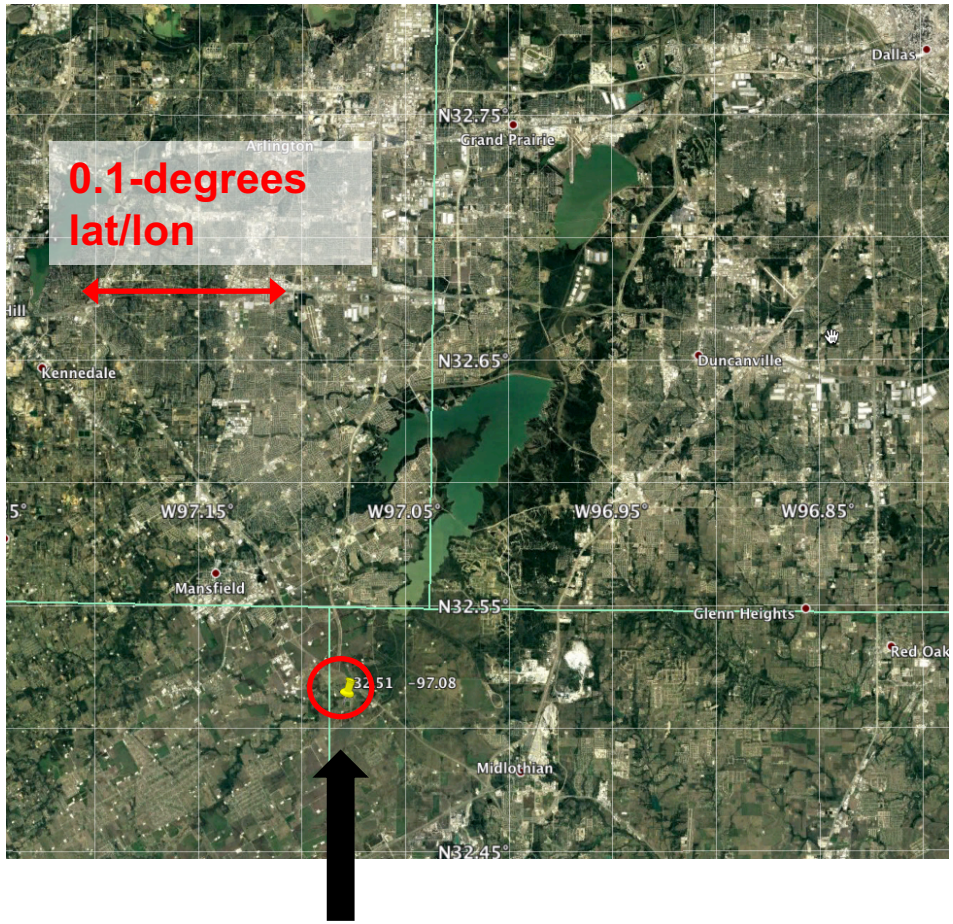
GPM overpass near the Texas-Louisiana border
18 April 2016, near 1228 UTC

Location A – non-raining



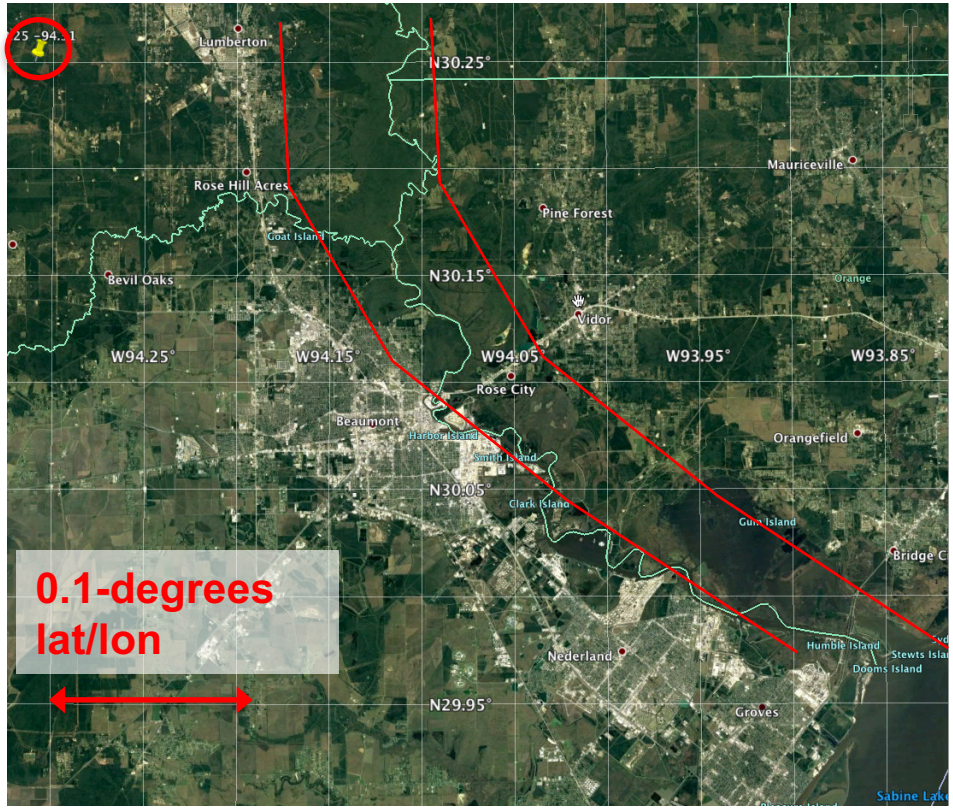
Location B – raining

GPM overpass near the Texas-Louisiana border
18 April 2016, near 1228 UTC



Location A
35-km SW of Dallas, TX, within 10-km of an inland reservoir

Location B
NW of Port Arthur, TX, within 15- of inland rivers/swamp that drain into Sabine Lake

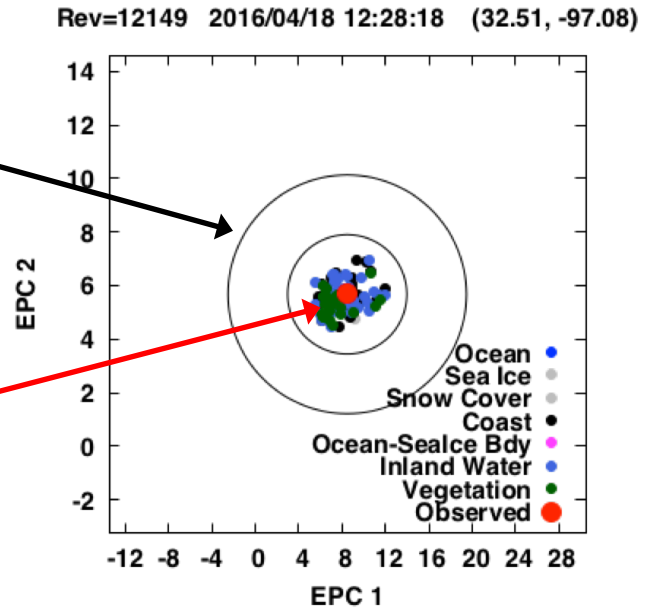


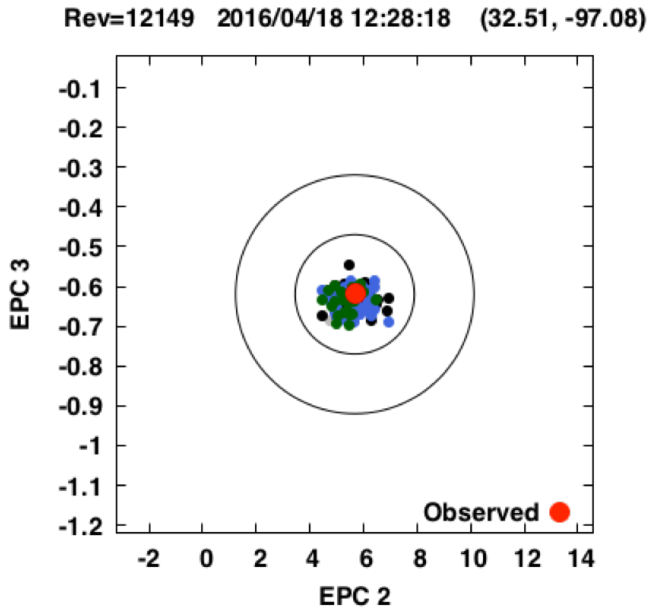
EPC-based search method, non-raining GMI location A
Top 100 ranked database candidates

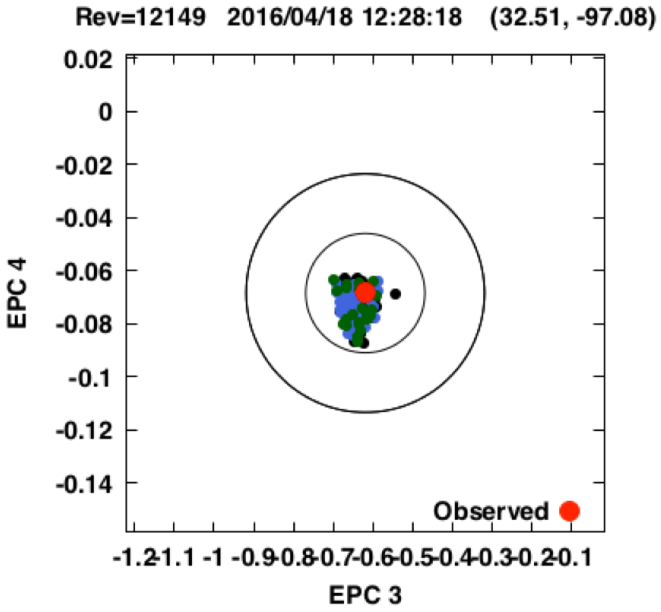
Inner and outer circles denote 0.25 and 0.50 EPC standard deviations about the GMI observation (red point), which was identified as TELSEM class 5

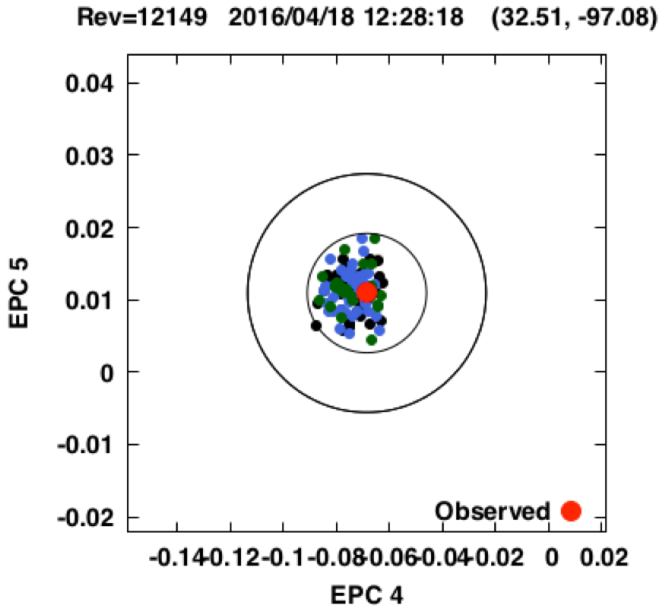
Candidates mostly carry the vegetation class (3-7), but some are coast and inland water

Very little displacement









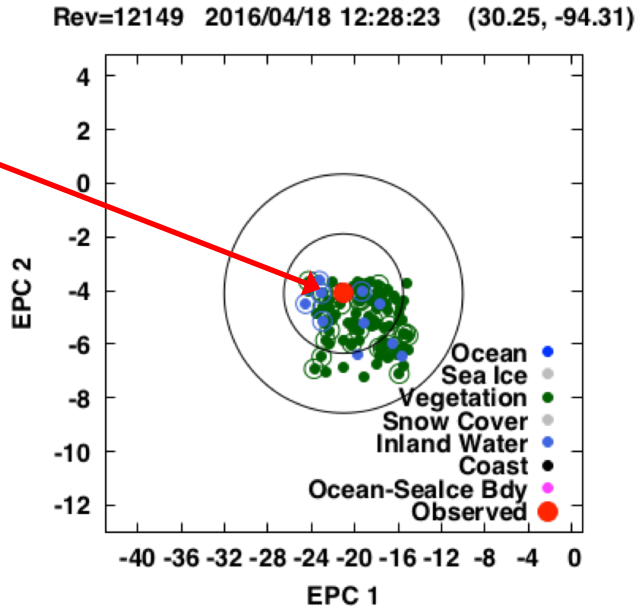
EPC-based search method, raining GMI location B
Top 100 ranked database candidates

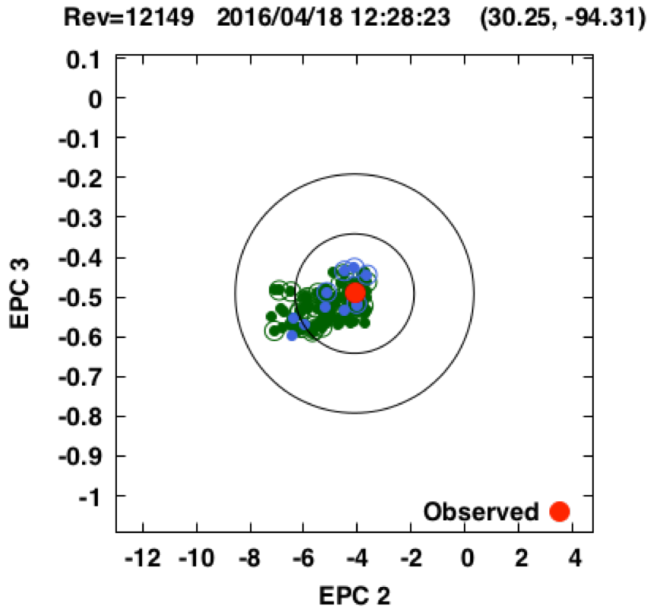
GMI observation (red point), identified as TELSEM class 5

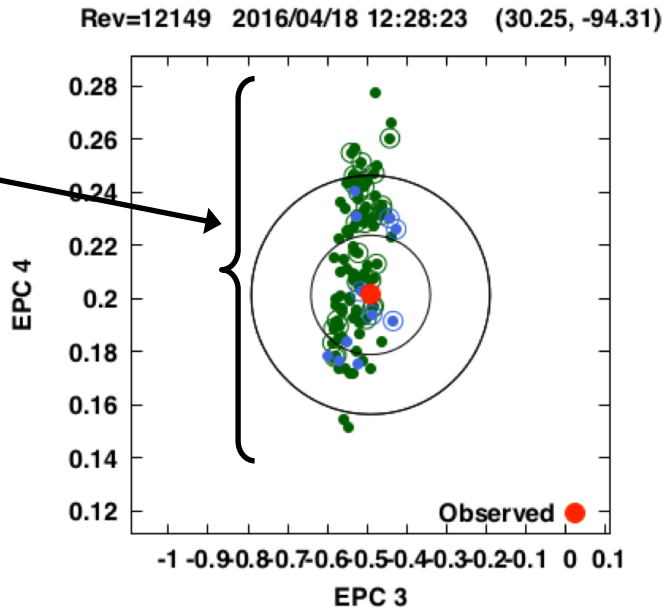
Candidates mostly carry the TELSEM vegetation class (3-7), but some are inland water

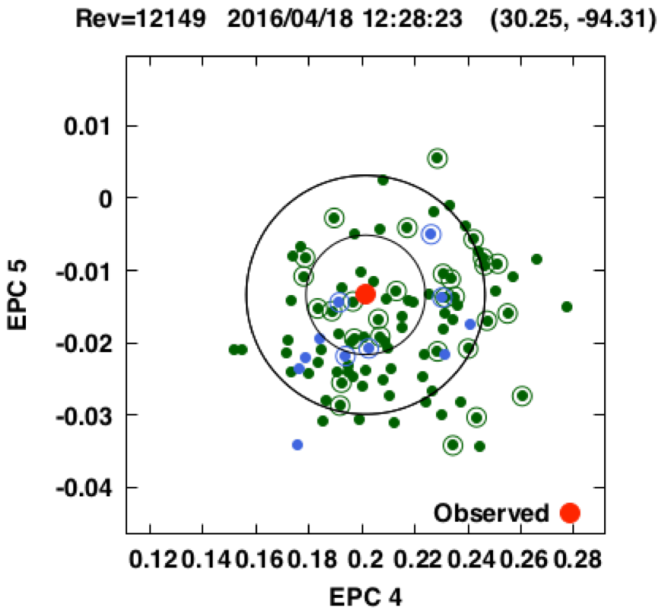
Displacement in EPC4 and above

Candidates where R > 30 mm/hr are encircled (CMB-NS retrieval)



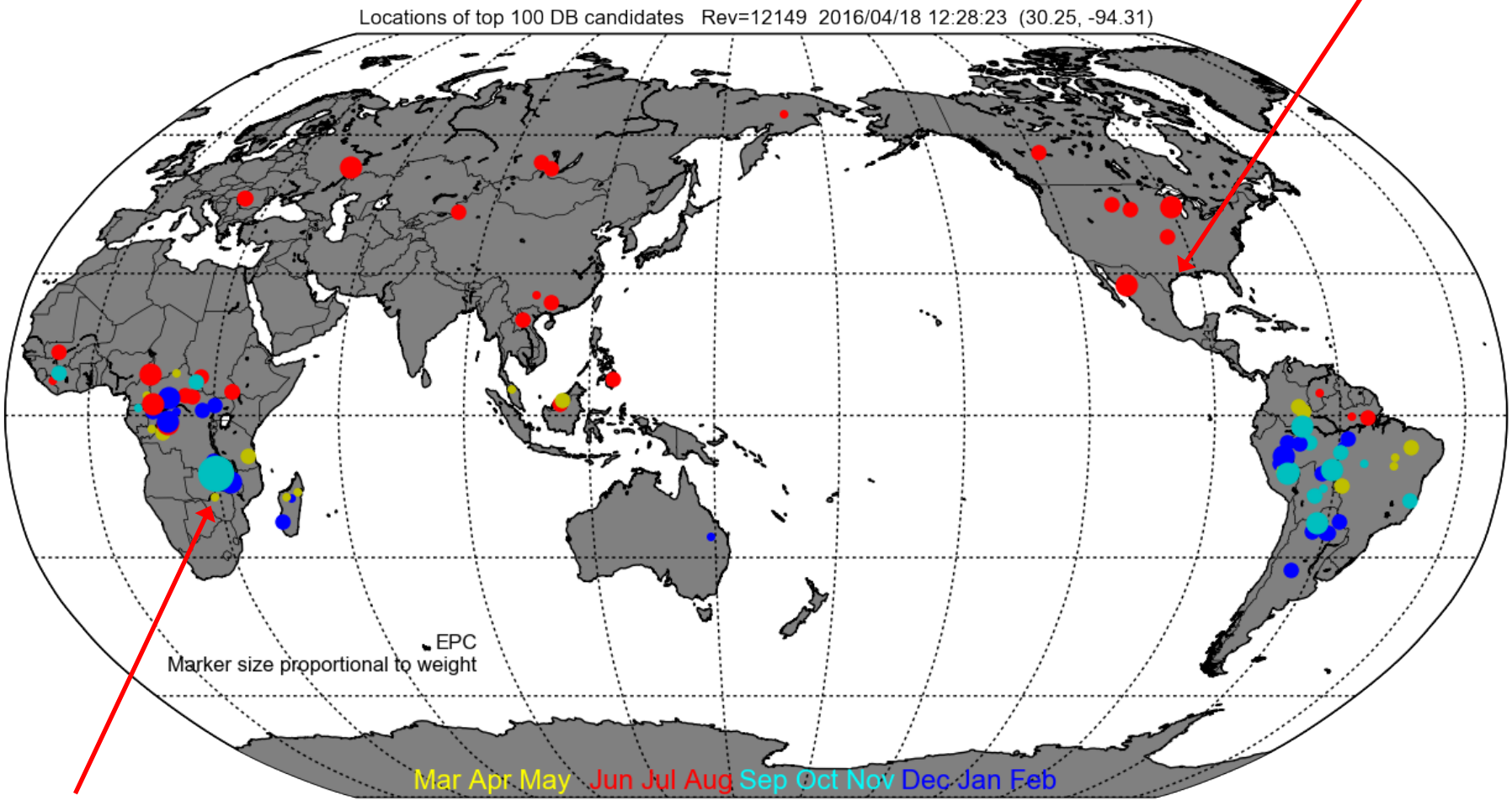






EPC-based search method, raining GMI location B
Locations of Top 100 ranked database candidates

Attempting a retrieval here



Top-ranked selection was located here

March-April-May **June-July-August**
September-October-November **December-January-February**

Nomenclature

1) **EPC-CMB-NS:** EPC-based estimate, where the combined (CMB) radar-radar algorithm (CORRA) Ku-band normal scan (NS) retrievals are weighted by distance in EPC space
2) **EPC-DPR-NS:** EPC-based estimate, where the radar-only (DPR) Ku-band normal scan (NS) retrievals are weighted by distance in EPC space

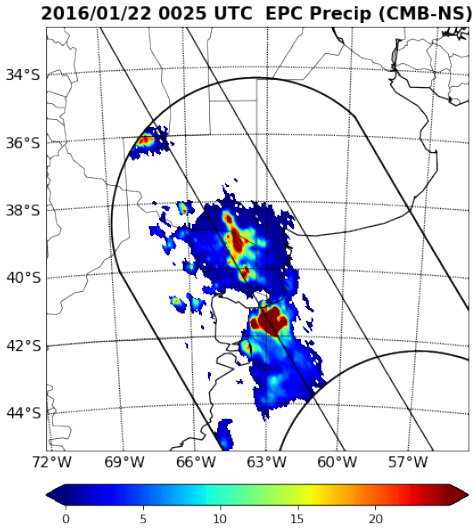
3) **EPC-CMB-MS:** Same as EPC-CMB-NS but using the (CORRA) Ku+Ka-band matched scan (MS) retrievals
4) **EPC-DPR-MS:** Same as EPC-DPR-NS, but using the radar-only (DPR) Ku+Ka-band band matched scan (MS) retrievals

For Version-4 processing and evaluation, only **EPC-CMB-NS** and **EPC-DPR-NS** retrievals were used

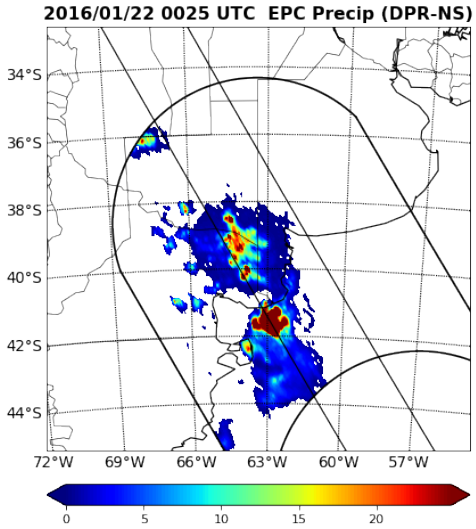
For Version-5 processing and evaluation, **EPC-CMB-MS** and **EPC-DPR-MS** retrievals were added

Example: Argentina 2016/01/22 0025 UTC

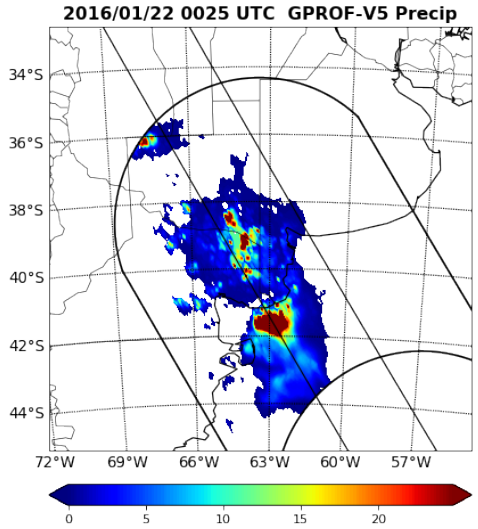
EPC-CMB-NS

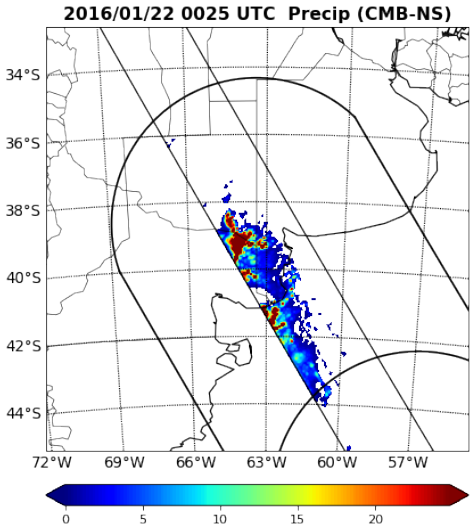


EPC-DPR-NS

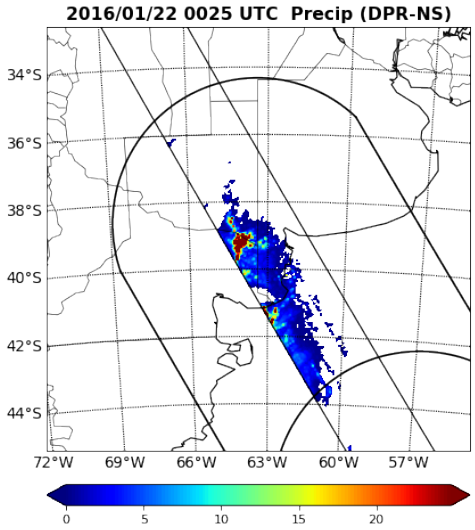


GPROF-V5

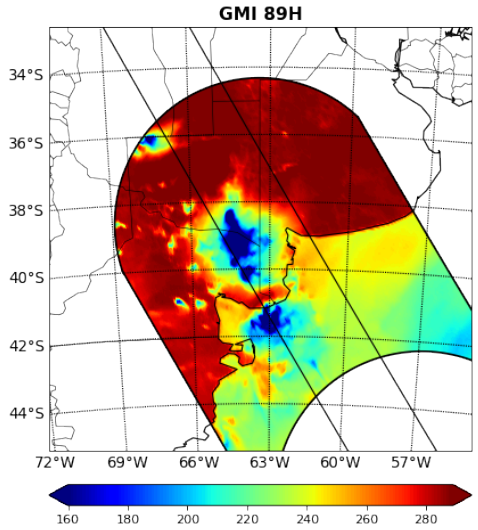




Actual CMB-NS



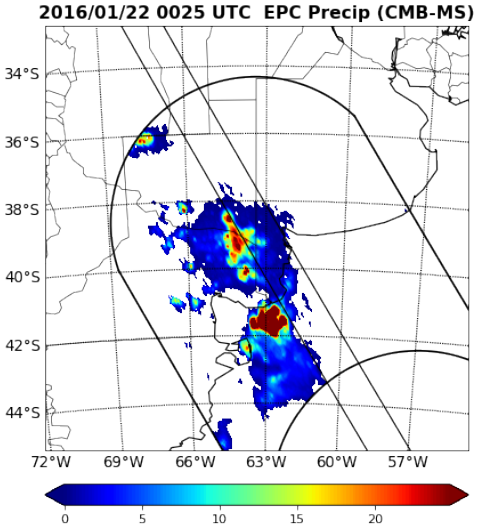
Actual DPR-NS



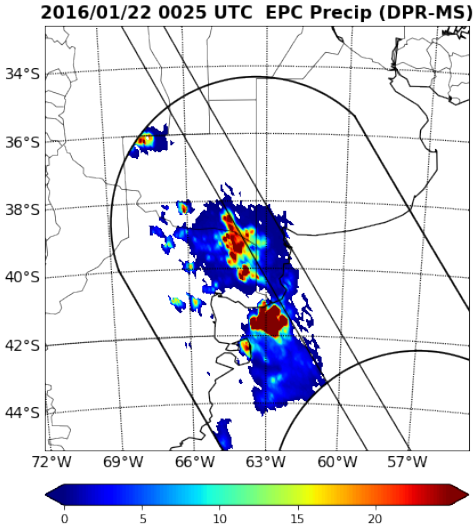
GMI 89H TB

Example: Argentina 2016/01/22 0025 UTC

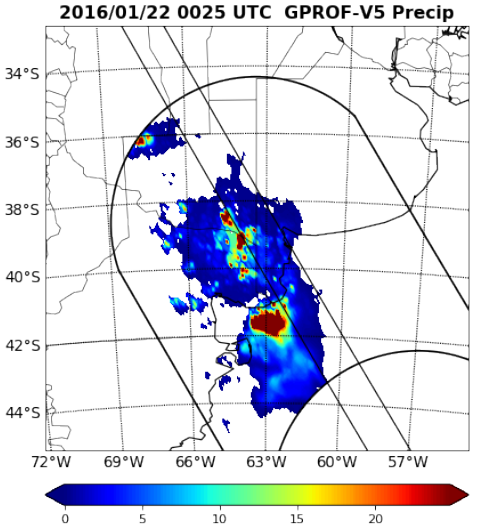
EPC-CMB-MS

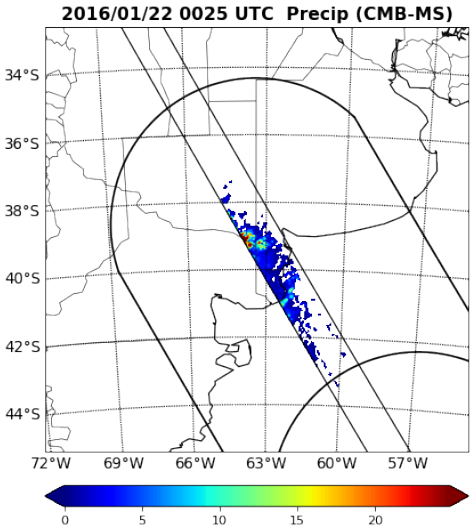


EPC-DPR-MS

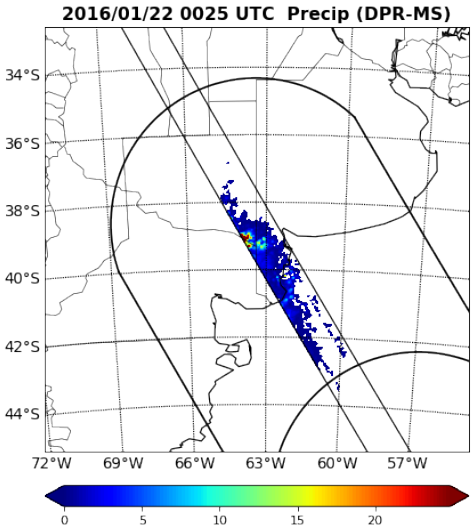


GPROF-V5

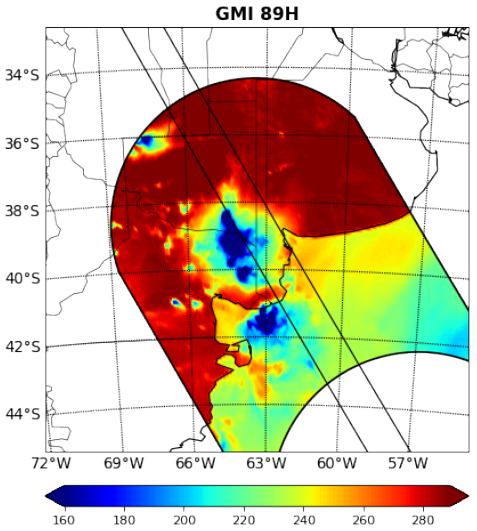




Actual CMB-MS



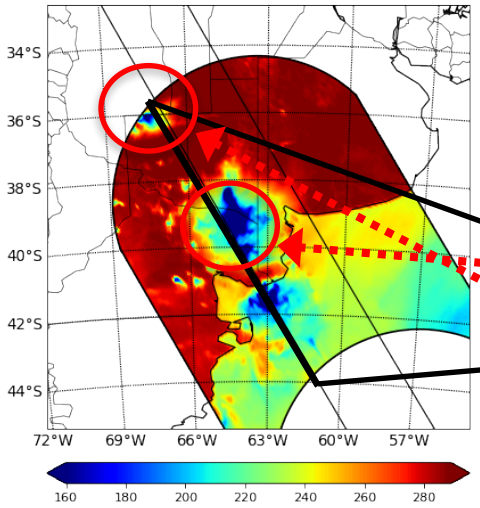
Actual DPR-MS

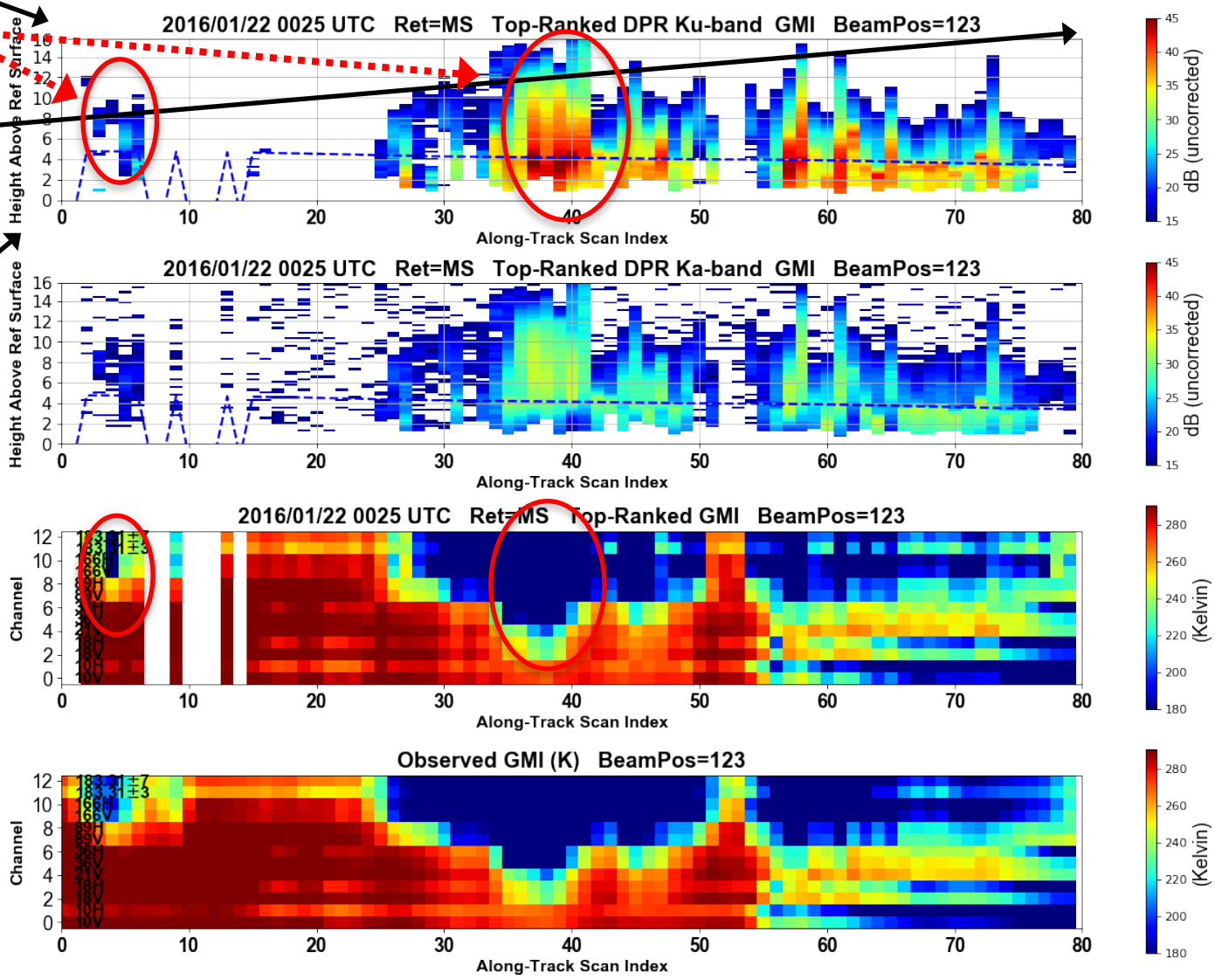


GMI 89H TB

Example: Argentina 2016/01/22 0025 UTC

The radiometer-only retrieval has only the TB observations at its disposal, no knowledge of the vertical structure. Use measured DPR profiles (in the databases) to assess if the selected profiles are consistent with the observed TB.





DPR Ku- and Ka-band measured reflectivity profiles from the top-ranked *a-priori* database candidate for the EPC-CMB-MS retrieval.

Trace of GMI TB 13 channels 10-183 GHz (bottom to top), from the top-ranked a-priori database candidate

Actual GMI TB observations

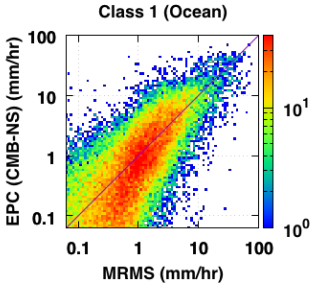
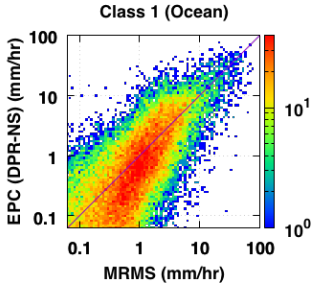
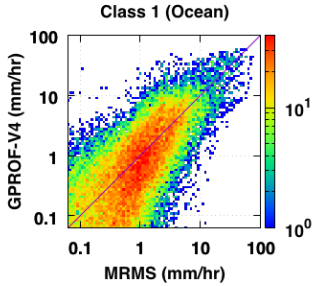
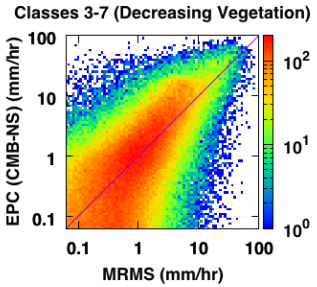
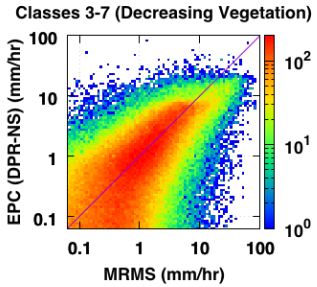
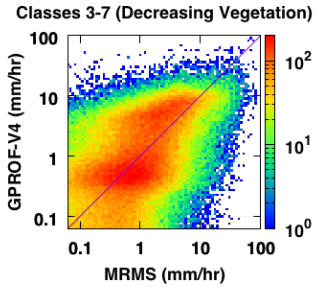
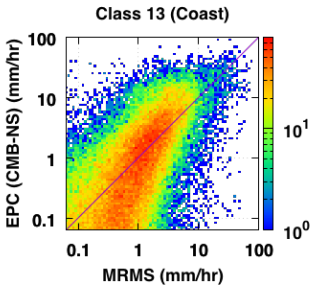
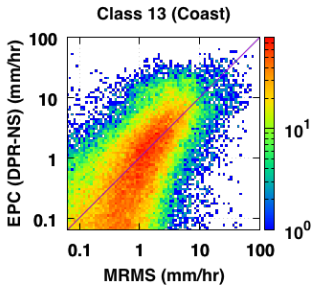
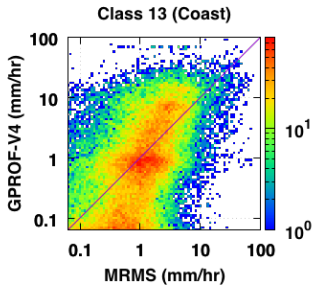
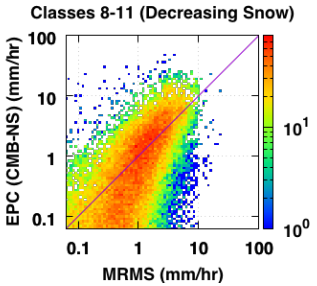
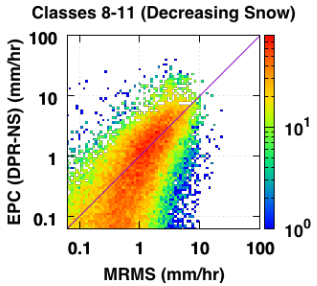
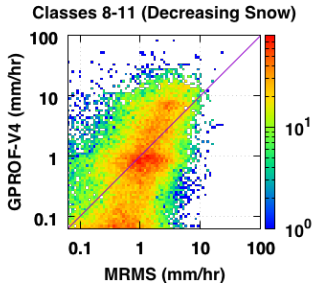
Independent Evaluation of EPC-based Estimates (Version 4 datasets)

Using NS (i.e., Ku-band only) products from the combined radar-radiometer (CORRA), and DPR radar-only (**EPC-CMB-NS**, **EPC-DPR-NS**)

Included GPROF-V4

Seven months of GMI-pixel matched MRMS (between Nov 2015 and Sep 2016) over continental US and surrounding waters

Overall Performance (Relative to GMI-Matched MRMS)
(seven months between Nov 2015 and Sep 2016)

	EPC (CMB-NS)	EPC (DPR-NS)	GPROF-V4
Ocean			
All Vegetation Classes (3-7)			
Coast			
All Snow Classes (8-11)			

2-D histograms

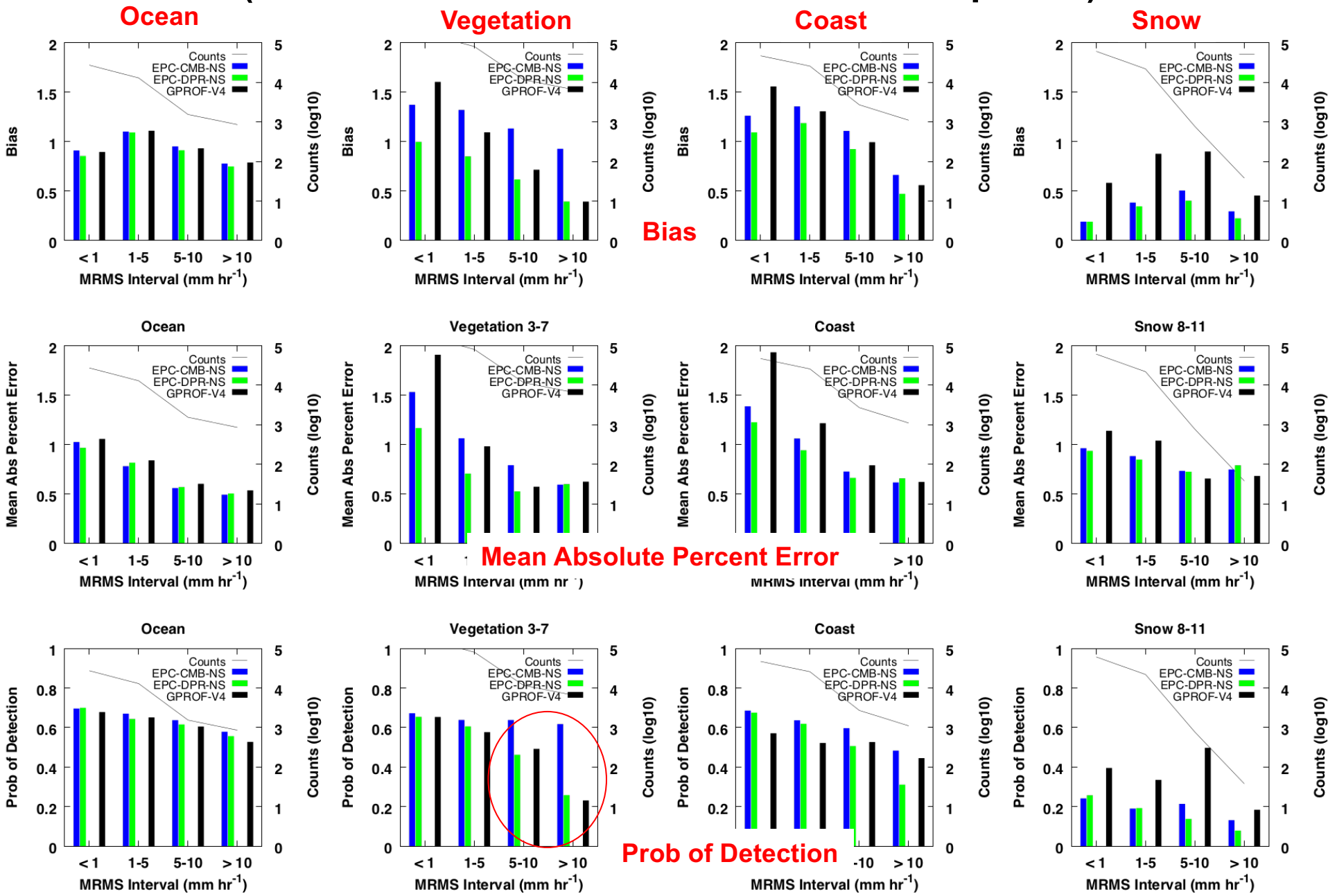
Each retrieval vs MRMS

Next slide:

EPC-CMB-NS
EPC-DPR-NS

GPROF-V5

Performance by Interval (Relative to GMI-Matched MRMS)
(seven months between Nov 2015 and Sep 2016)



Independent Evaluation of EPC-based Estimates (Version 5 datasets)

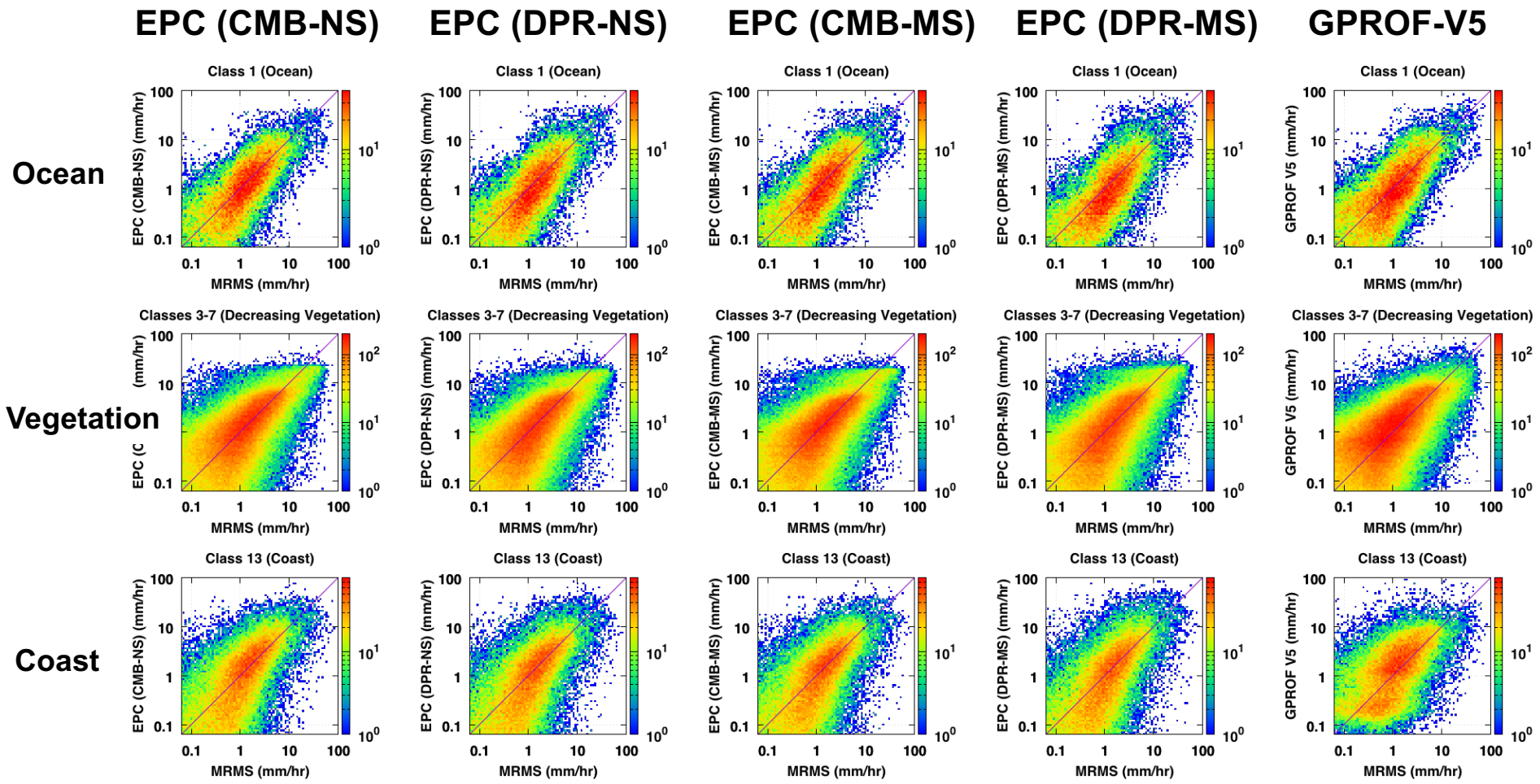
Using both NS (Ku-band only) and MS (Ku+Ka-band) products from the combined radar-radiometer (CORRA) and DPR radar-only (**EPC-CMB-NS, EPC-DPR-NS**, **EPC-CMB-MS, EPC-DPR-MS**)

Included GPROF-V5

Same seven months of GMI-pixel matched MRMS (between Nov 2015 and Sep 2016) over continental US and surrounding waters

Didn’t finish snow cover yet

Overall Performance (Relative to GMI-Matched MRMS)
(seven months between Nov 2015 and Sep 2016)

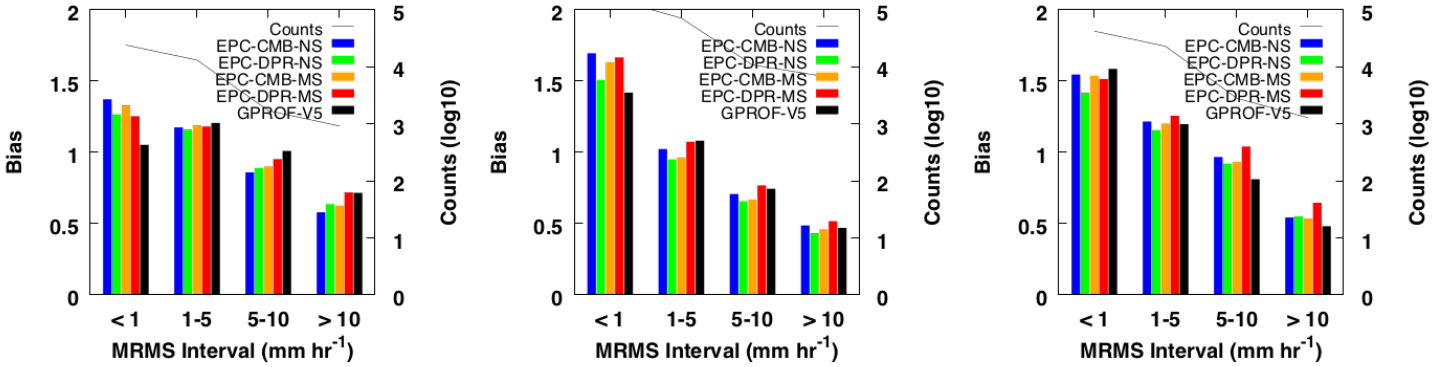


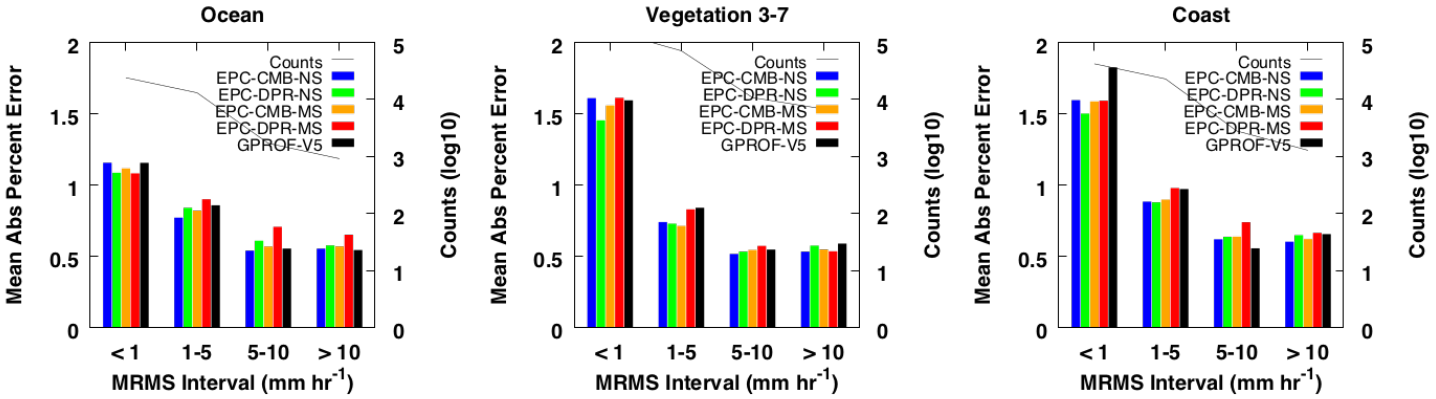
Snow (not completed yet)

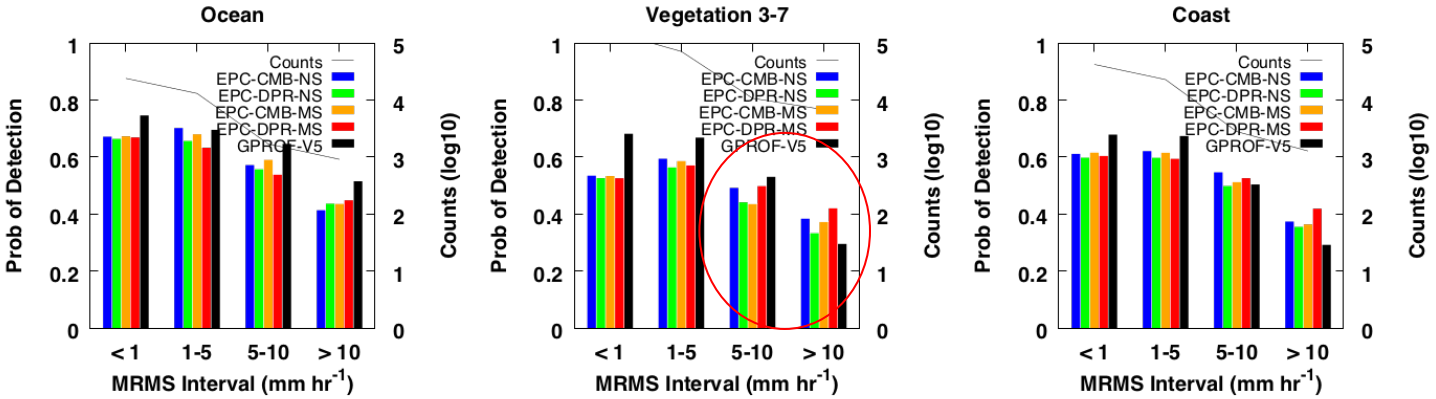
Performance by Interval (Relative to GMI-Matched MRMS)
(seven months between Nov 2015 and Sep 2016)

Ocean | **Vegetation** | **Coast** | **Snow**

Not completed yet







EPC-CMB-NS
EPC-DPR-NS

EPC-CMB-MS
EPC-DPR-MS

GPROF-V5

Results from Verification using GPM V4 & V5 Datasets

Version-4

In general, EPC-based indexing and distance weighting picked up more heavy rain events using CMB-NS than by using DPR-NS

No significant differences amongst retrievals over ocean

In general, EPC-CMB-NS outperforms EPC-DPR-NS everywhere

“Double clump” in GPROF-V4 over vegetation.

GPROF-V4 superior over snow cover.

Version-5

In general, EPC-based estimates using the four GPM-core retrievals (CMB-NS, CMB-MS, DPR-NS, DPR-MS) perform fairly similar.

Past 10 mm/hr, EPC-based estimates show higher detection rates over vegetation and coast

For GMI pixels where TELSEM indicated vegetated classes, GPROF performs much better at detection relative to its V4 counterpart.

“Double clump” is lessened in GPROF over vegetation. Still present for coast.

Summary and Suggestions

- Use of the EPC as a indexing/search method exhibits potential for a single passive MW retrieval that adapts to ocean/land surface variability, from an observational (or modeled, presumably) *a-priori* dataset

- Removes surface classification index and (mostly) the need for model ancillary data. Poor over-snow performance (EPC did not use a daily snow mask, nor 166/183 GHz channels).

- Adaptable for each type of passive MW sensor in the TRMM or GPM constellation (that have some surface-sensitive channels)

- **Suggestion 1**: In addition to conventional surface rainrate, verify that realistic vertical structures are being selected (native measured DPR Z profiles were used) (Pierre Kirstetter's talk this AM on conv/strat).

- **Suggestion 2**: ATMS data in PPS carry 23-183 GHz channel set. Addition of AMSU-A (23/31 GHz) to AMSUB/MHS data would enable consistency amongst MW sounder retrievals (exception being SAPHIR).

Extra

Weighting of Candidate Solutions

Distance in EPC space

$$d_{EPC} = \frac{1}{N}\sum_{i=1}^{N}\left(\left(u_i^{obs} - u_i^{DB}\right)/\sigma_i^{DB}\right)^2 \quad N = 11$$

$$d_{TB} = \frac{1}{N}\sum_{i=1}^{N}\left(\left(TB_i^{obs} - TB_i^{DB}\right)/\sigma_i^{DB}\right)^2 \quad N = 9 \text{ or } 13$$

Distance in TB space

TPW search
Weighting done by proximity to column water vapor, Ts (or T2m) values, the same TELSEM class index, and distance in TB space.

EPC search
Weighting done in EPC space only

Both search methods interrogate the identical database

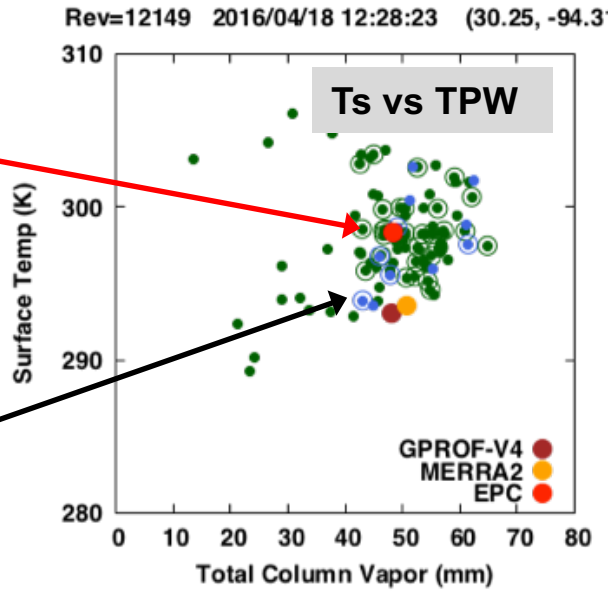
Use the TELSEM index for evaluation purposes

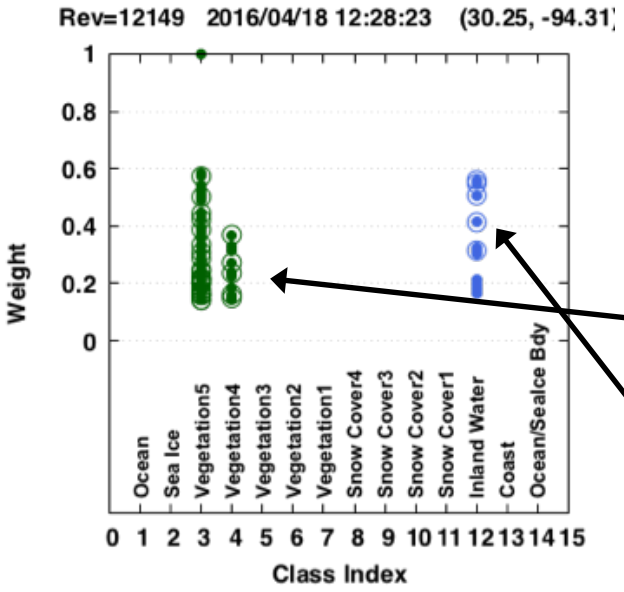
$$\hat{R}_{EPC} = \sum_{i=1}^{N} w_i R_i^{DB} \Big/ \sum_{i=1}^{N} w_i$$

EPC-based search method, raining GMI location B
Top 100 ranked database candidates – Ts and TPW

GMI observation (red point), identified as TELSEM class 5

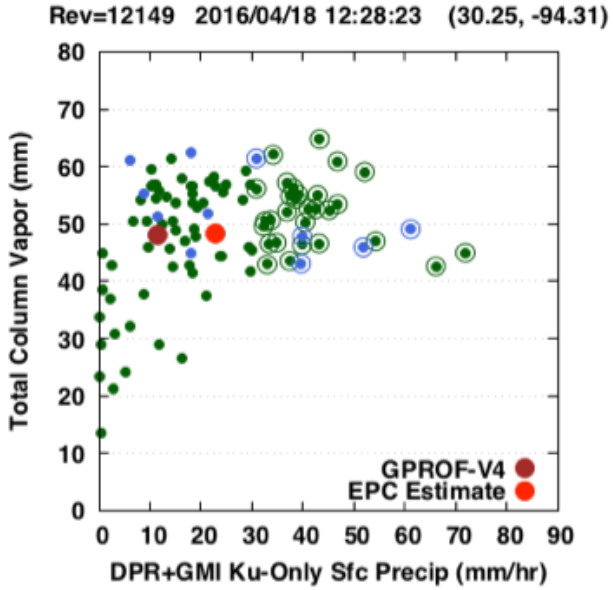
Candidates cover an expanded range in associated Ts-TPW space

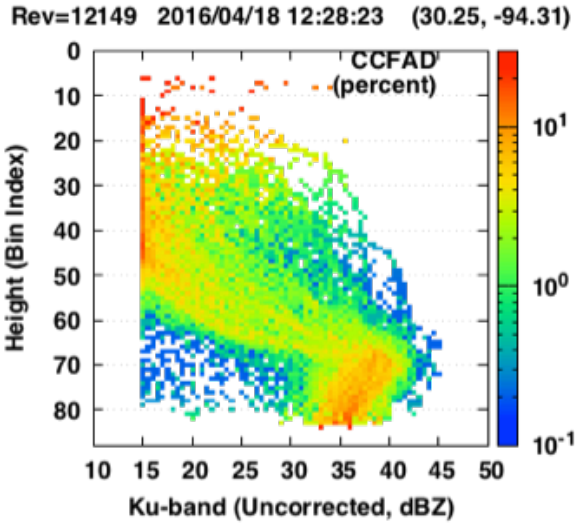




Candidates mostly carry the TELSEM vegetation class (3-7), but some are inland water

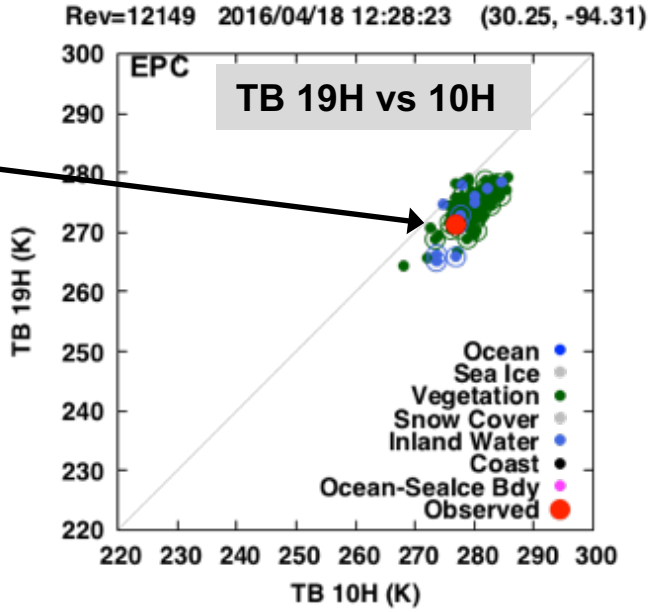
Candidates where R > 30 mm/hr are encircled (CMB-NS retrieval)

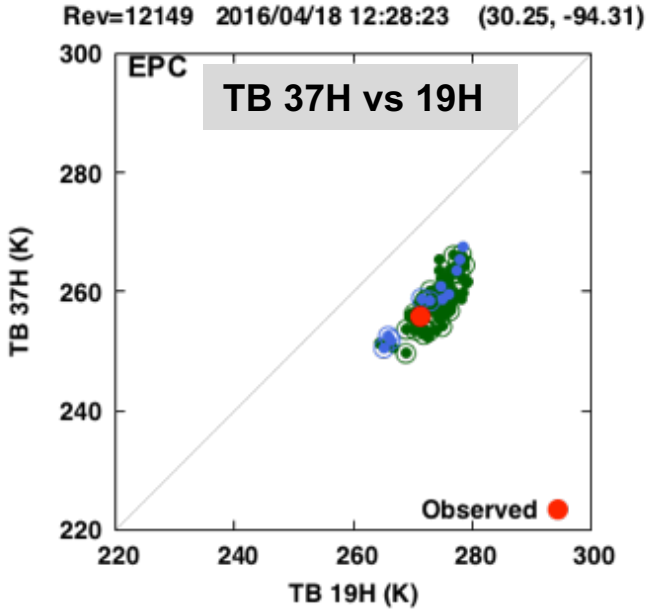


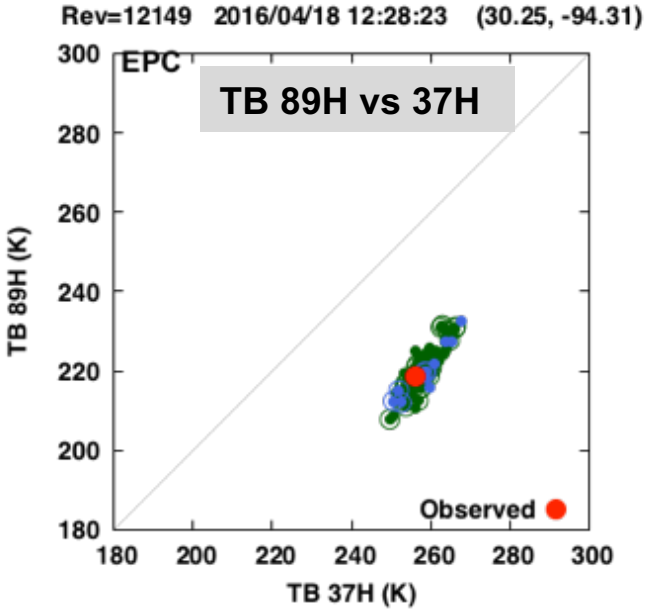


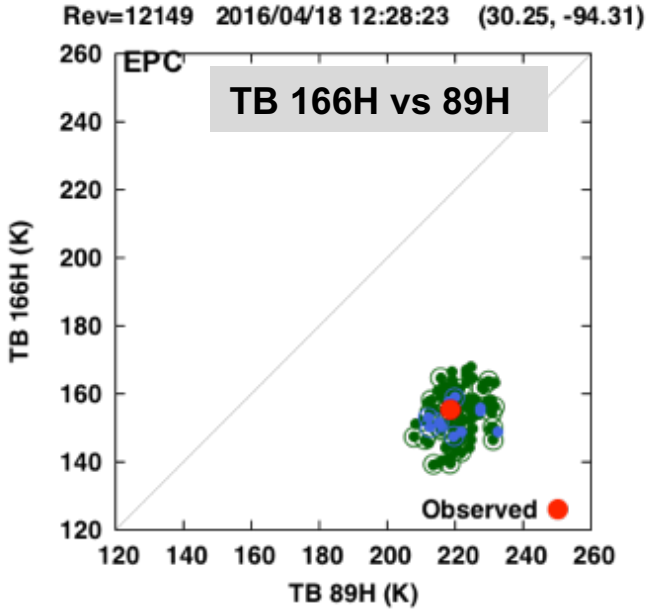
EPC-based search method, raining GMI location B
Top 100 ranked database candidates - TB

GMI observation (red point), identified as TELSEM class 5



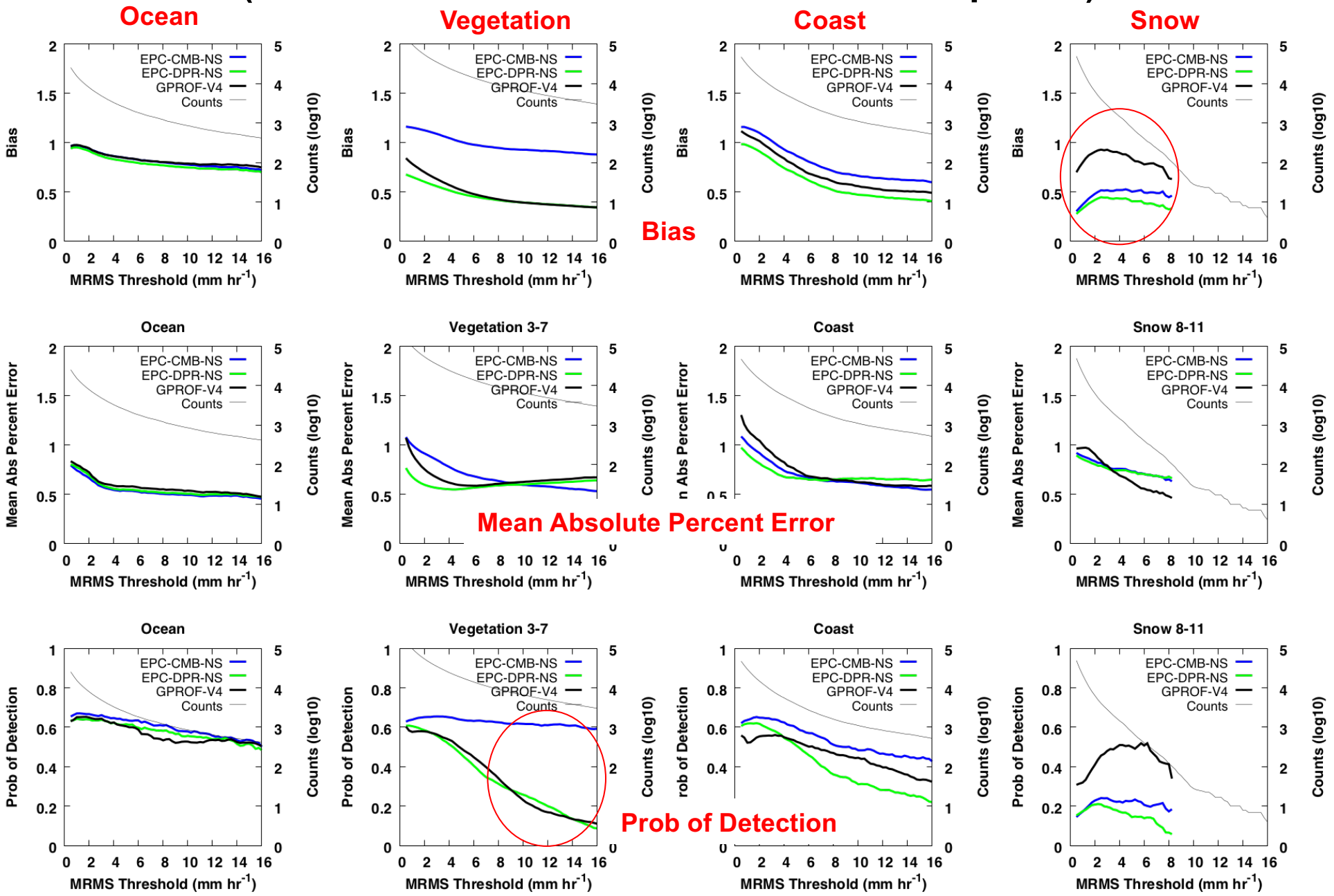






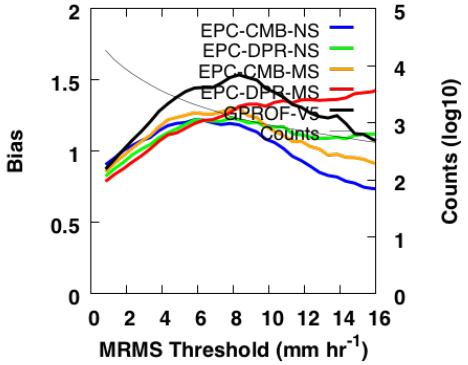
Candidates where R > 30 mm/hr are encircled (CMB-NS retrieval)

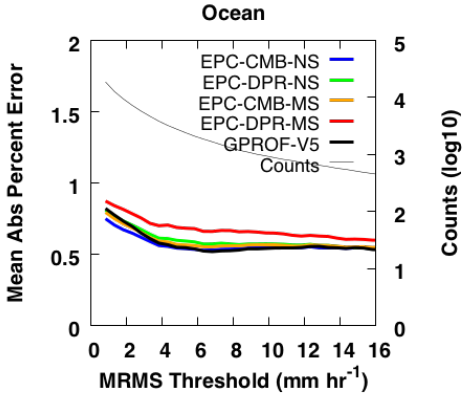
Performance by Threshold (Relative to GMI-Matched MRMS)
(seven months between Nov 2015 and Sep 2016)

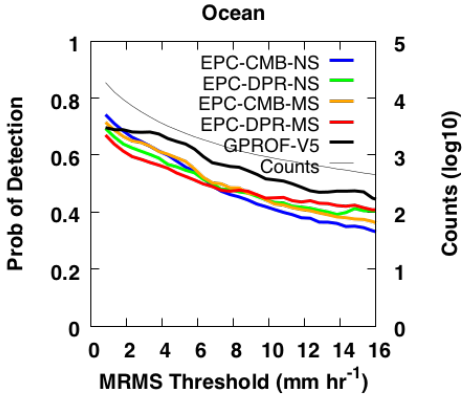


Performance by Threshold (Relative to GMI-Matched MRMS)
(seven months between Nov 2015 and Sep 2016)

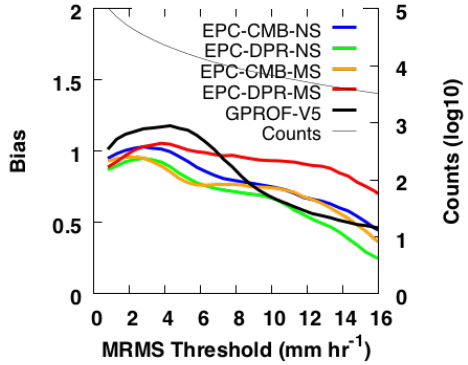
Ocean

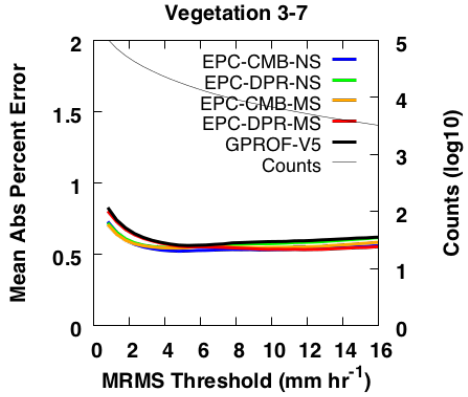


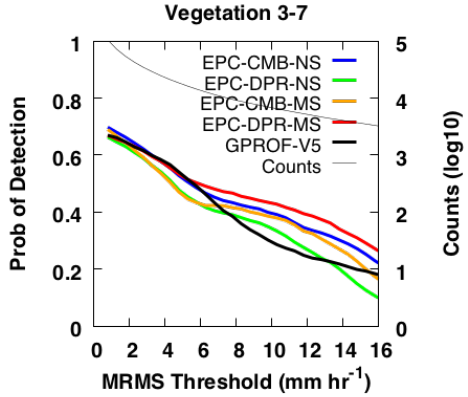




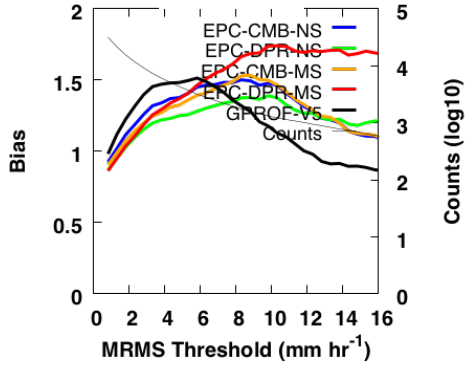
Vegetation

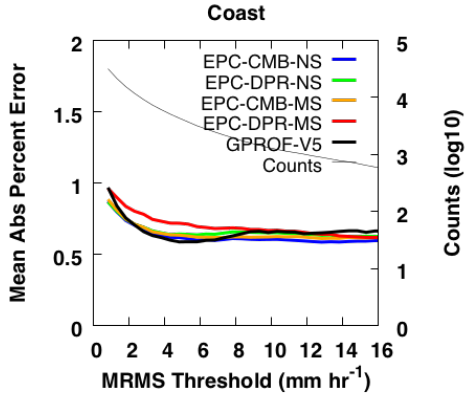


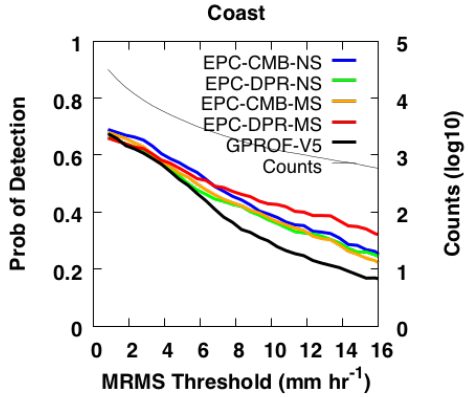




Coast







Snow

Not completed yet

EPC-CMB-NS
EPC-DPR-NS

EPC-CMB-MS
EPC-DPR-MS

GPROF-V5